

High Speed Infrared Temperature Mapping of a Rotating Target (Automotive Brake Rotor)

FORD

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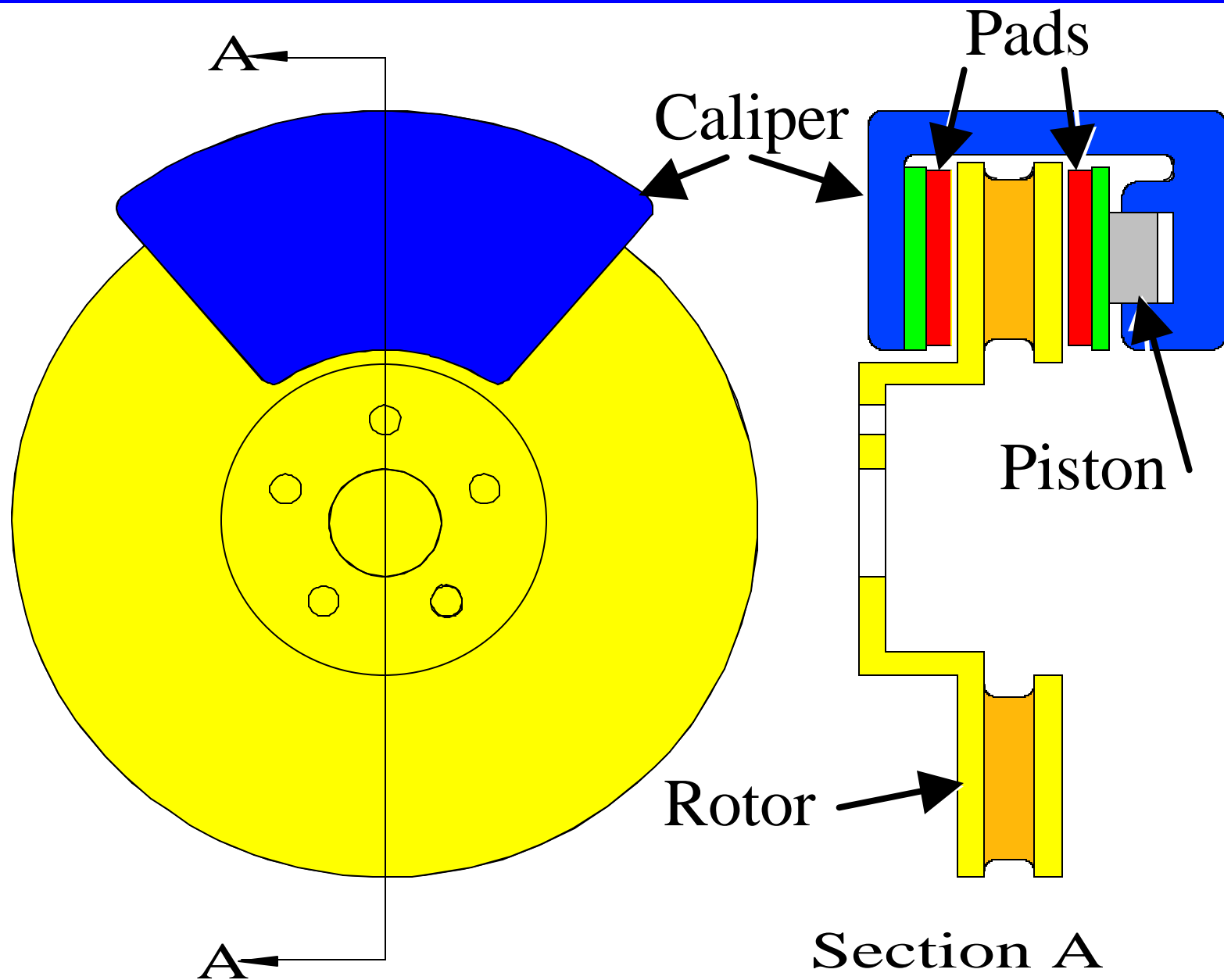
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Overview

- Introduction
- Infrared system descriptions
- Infrared system capabilities
- Comparison of the results
- System Utilization
- Conclusions

Brake System Being Studied



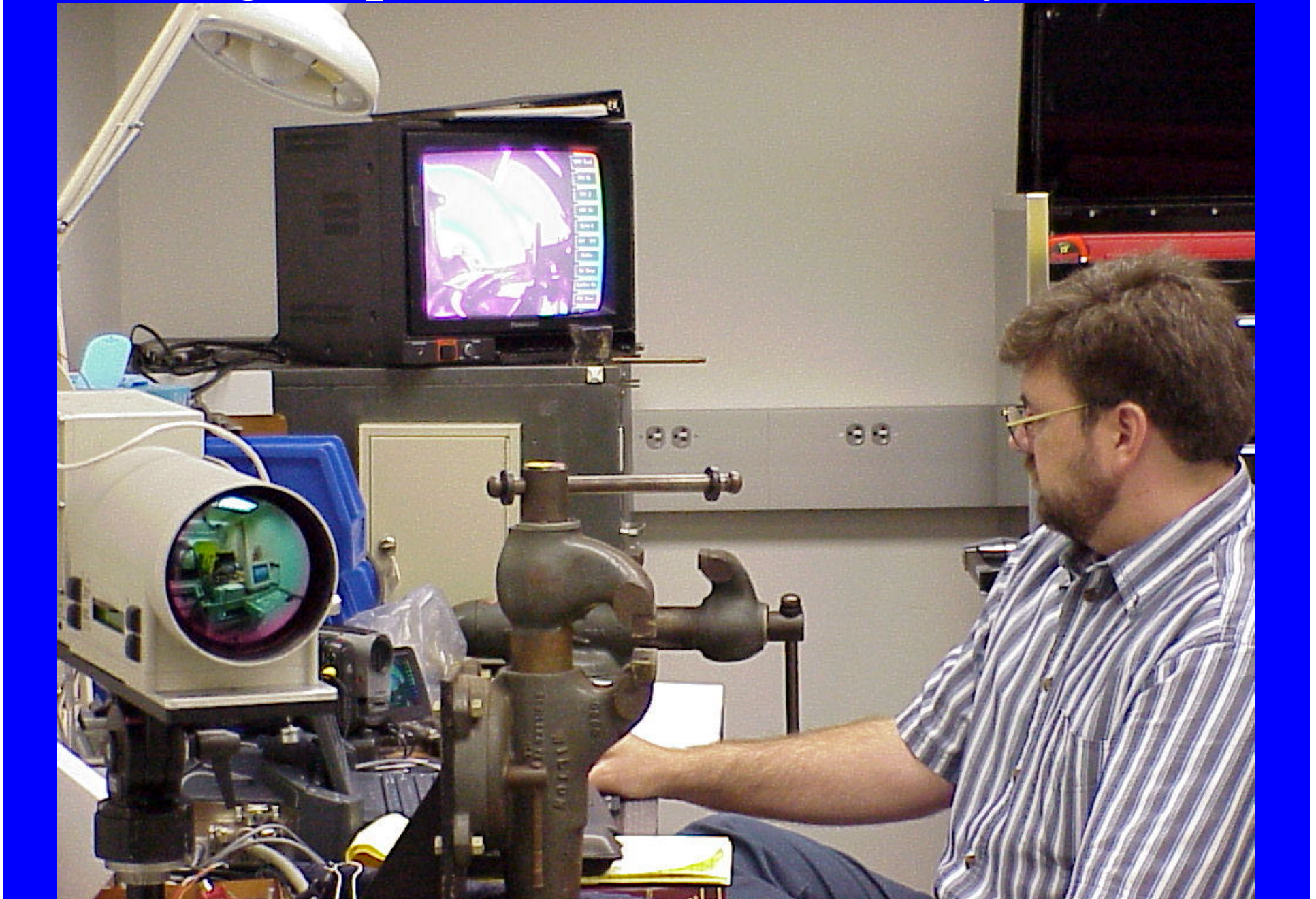
History

- Torque variation of brakes causes pulsations
- High speed **IR CAMERA** system indicated hot spots
- Needed to improve the capabilities for data analyses
- Initiated development of a high speed **IR SENSOR** system

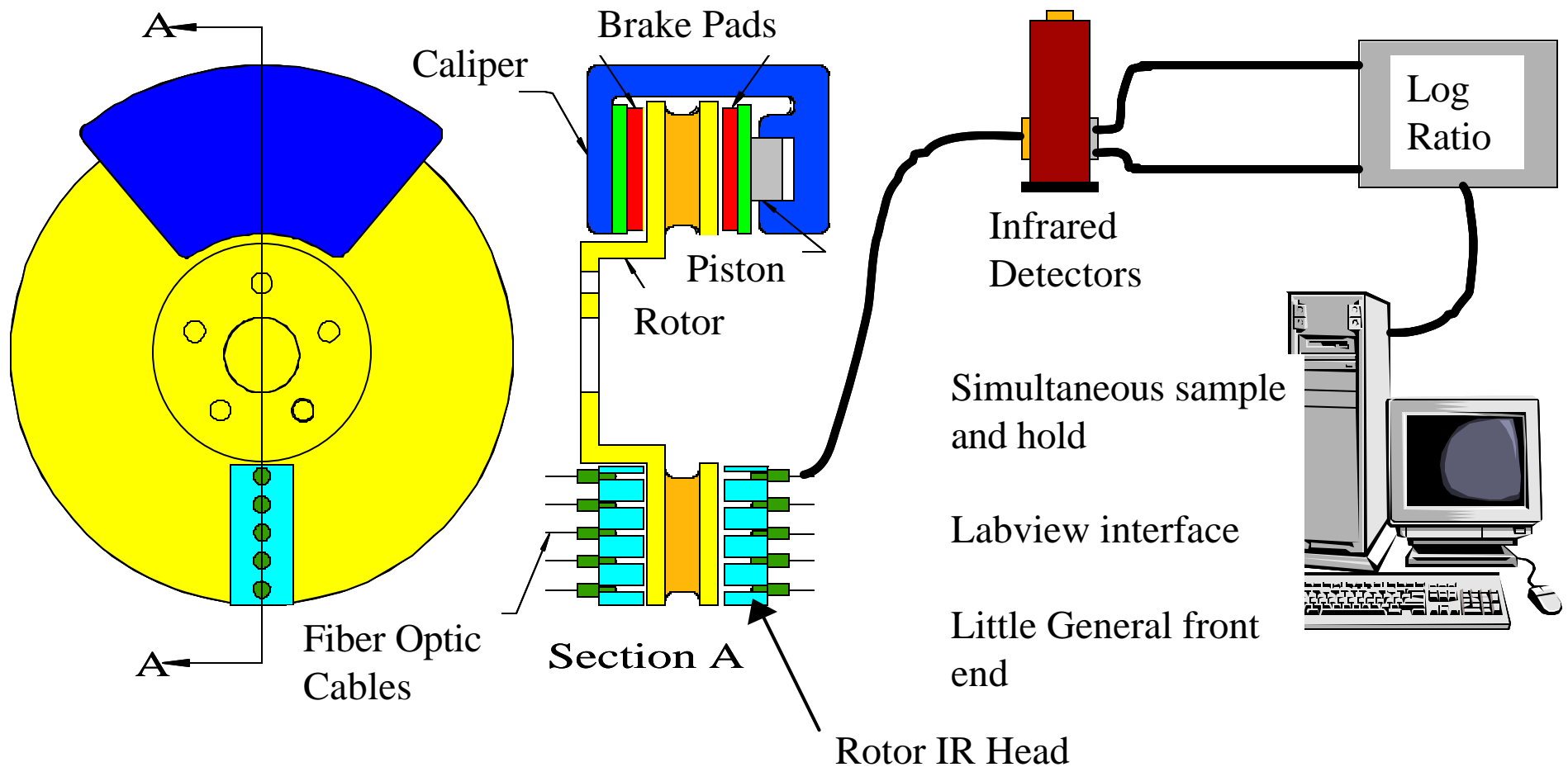
High Speed **IR CAMERA** System

- Radiance-HS by Raytheon
- High frame rate with variable integration time of 14 milliseconds to 2 microseconds
- Snapshot mode
- External trigger
 - ORNL custom design time delay
- Real time video output

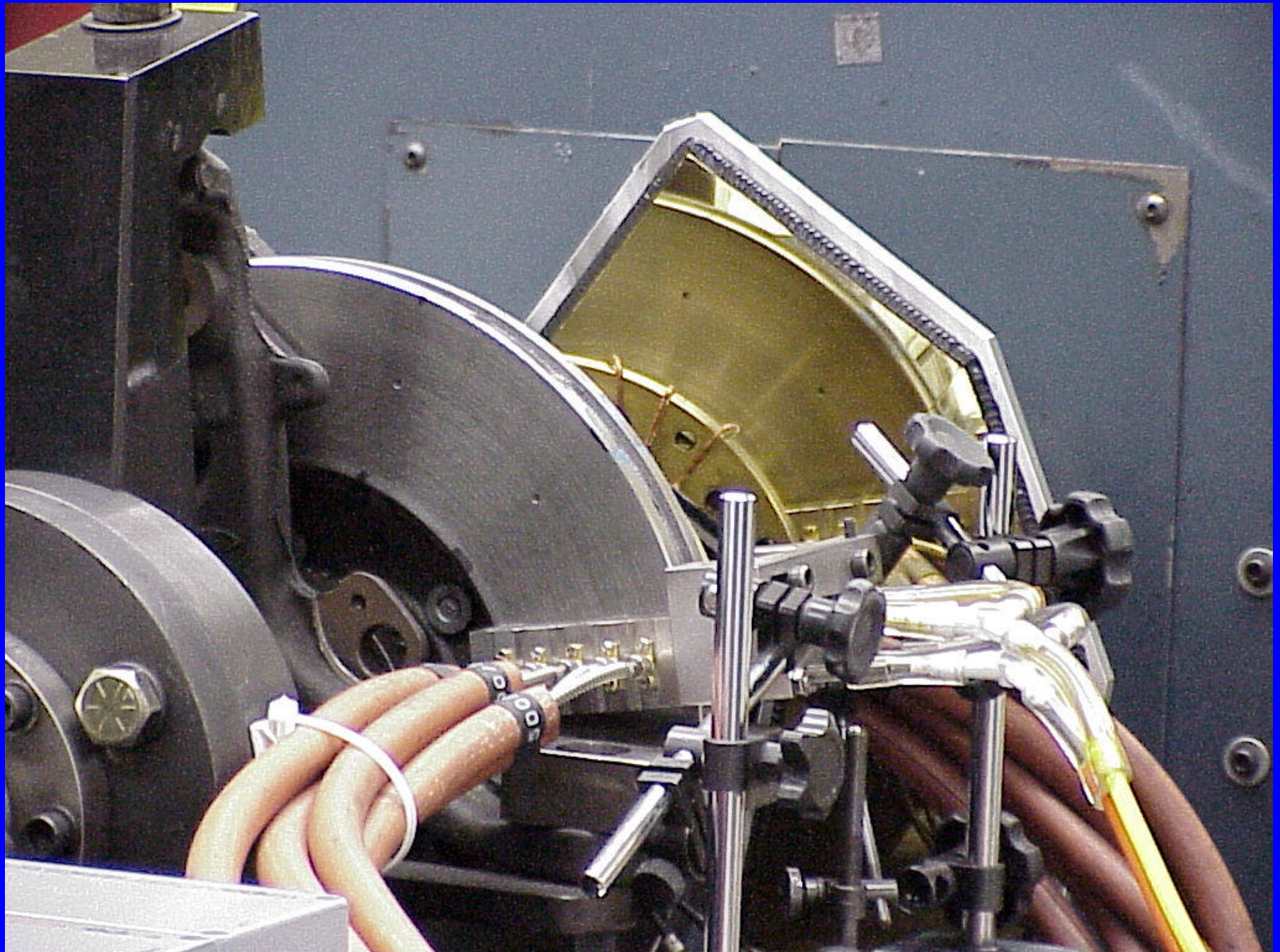
High Speed IR CAMERA System



INFRARED SENSOR System



View of Rotor from IR CAMERA



IR SENSOR System Installed



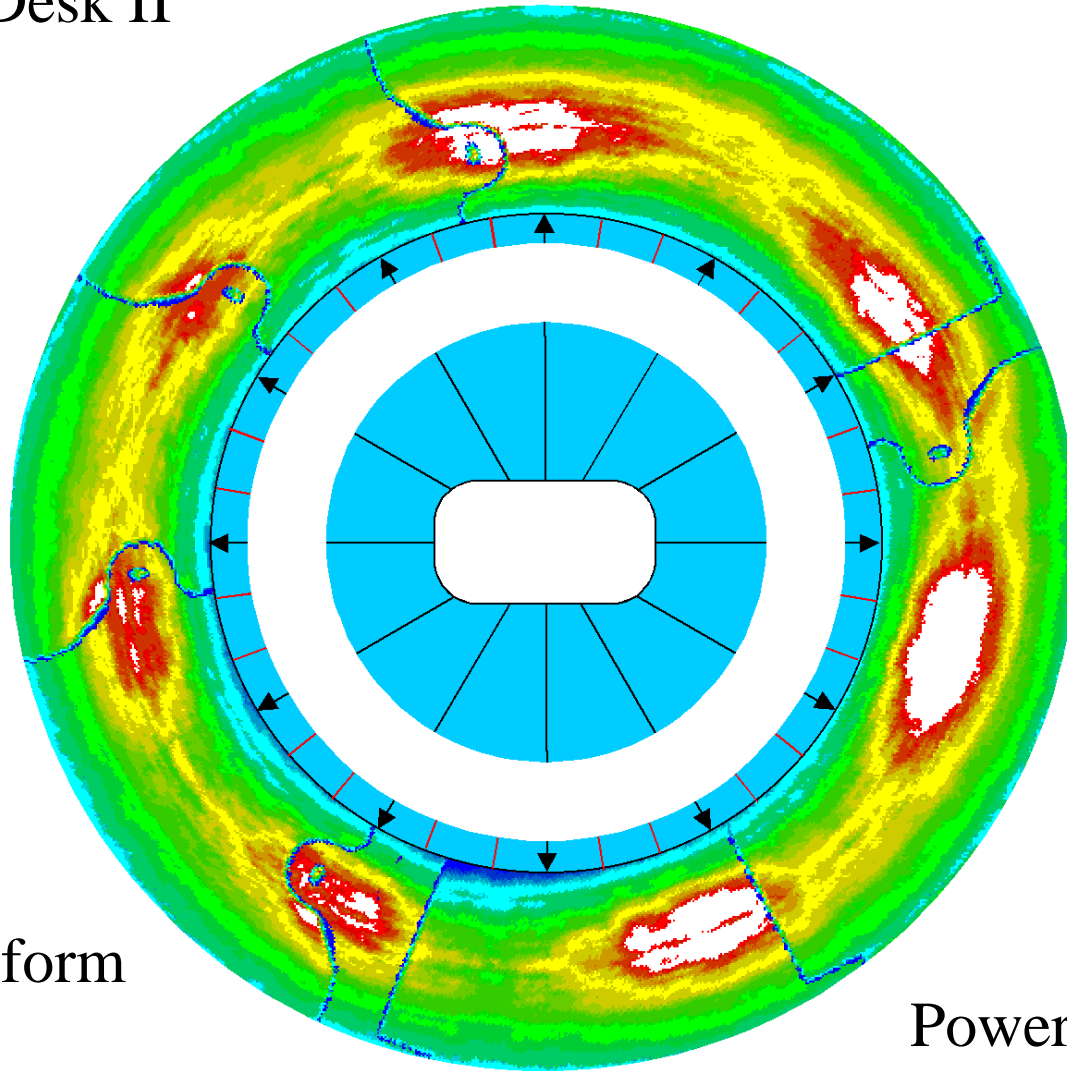
IR CAMERA Capabilities

- Real time visualization of section of rotor
- Time delay trigger permitted viewing of different sections of rotor
- Composite picture of the rotor could be generated in post test mode.
- Direct correlation of temperature data with other parameters difficult
- Temperature data sensitive to emissivity
- Filters limited low end to 200 C

IR CAMERA Composite Picture

ImageDesk II

Corel Photo-Paint 8



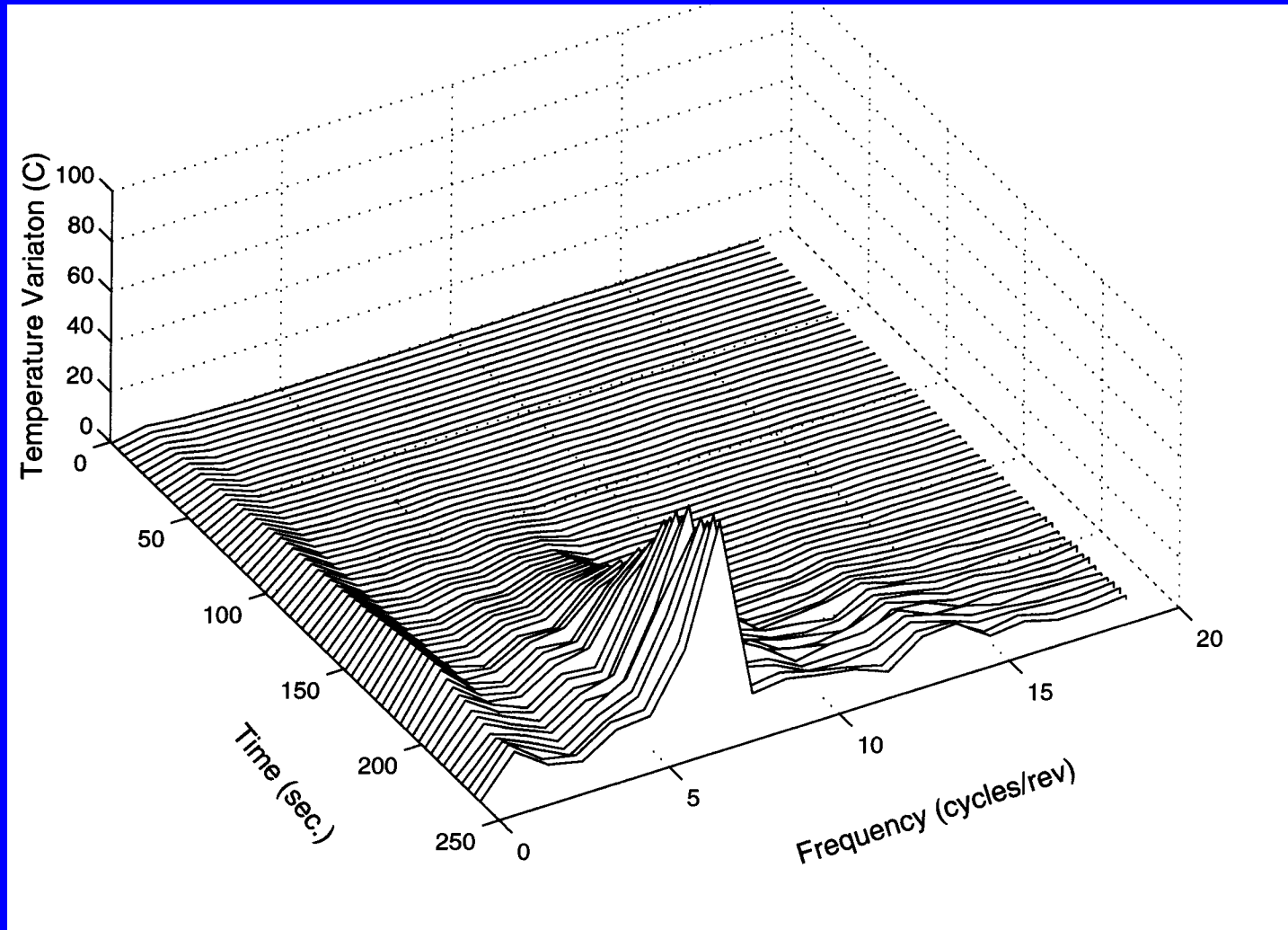
Transform

Powerpoint

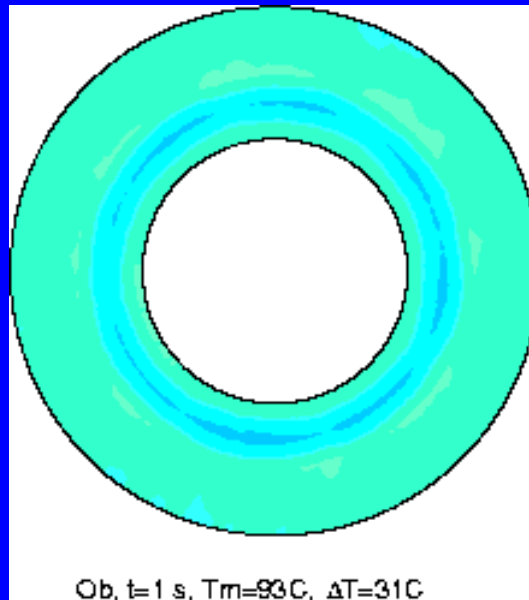
IR SENSOR System Capabilities

- Temperatures less sensitive to emissivity
- Temperature capability to 100 C or less
- Excellent for post processing of the data
 - Correlation analyses
 - movies of hot spot formation
 - quick feedback on individual channels after test
- No real time feedback during test
- LITTLE GENERAL converts binary to EXCEL output which is manipulated by MATLAB for data analyses
- Large data files >90 MB

Fast Fourier Transform Analyses

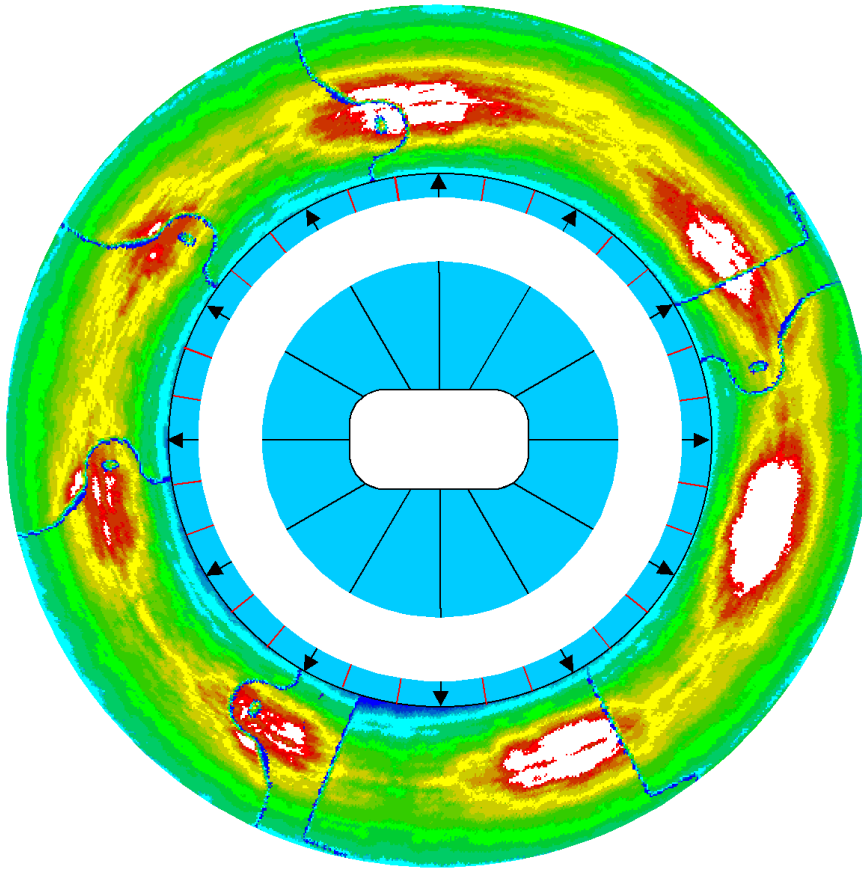


Movie from IR SENSOR Sequence

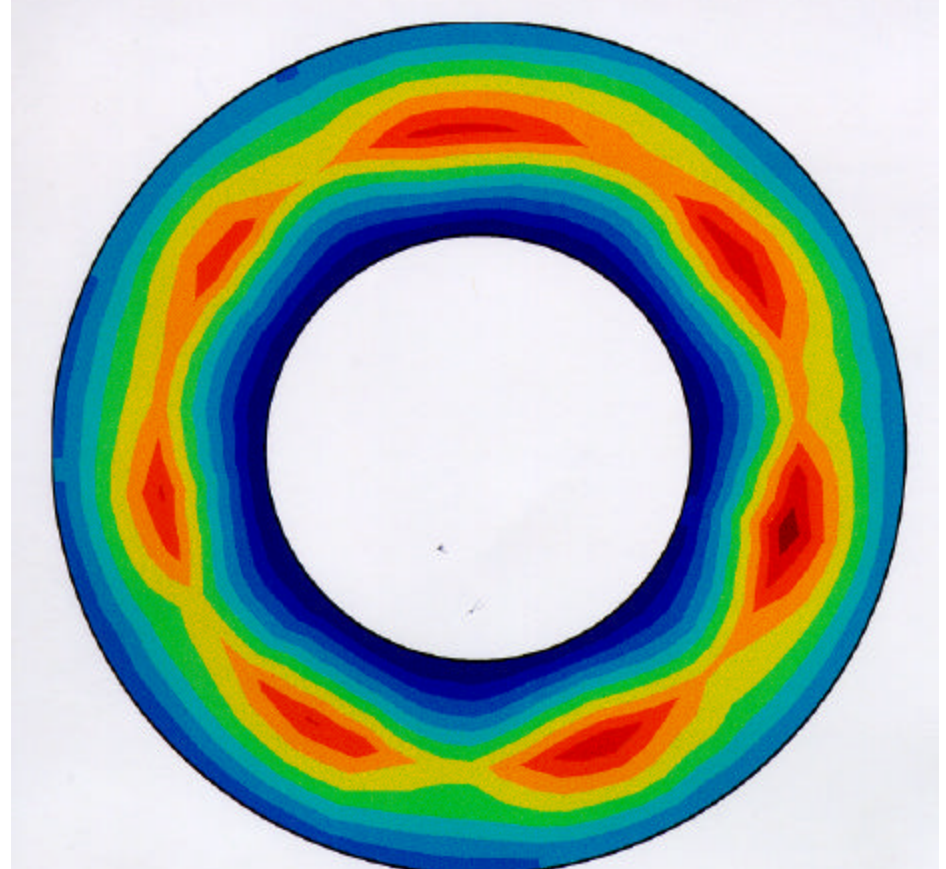


Comparison of Results with
the
IR CAMERA & IR SENSOR
System

Hot Spot Comparison



IR CAMERA System



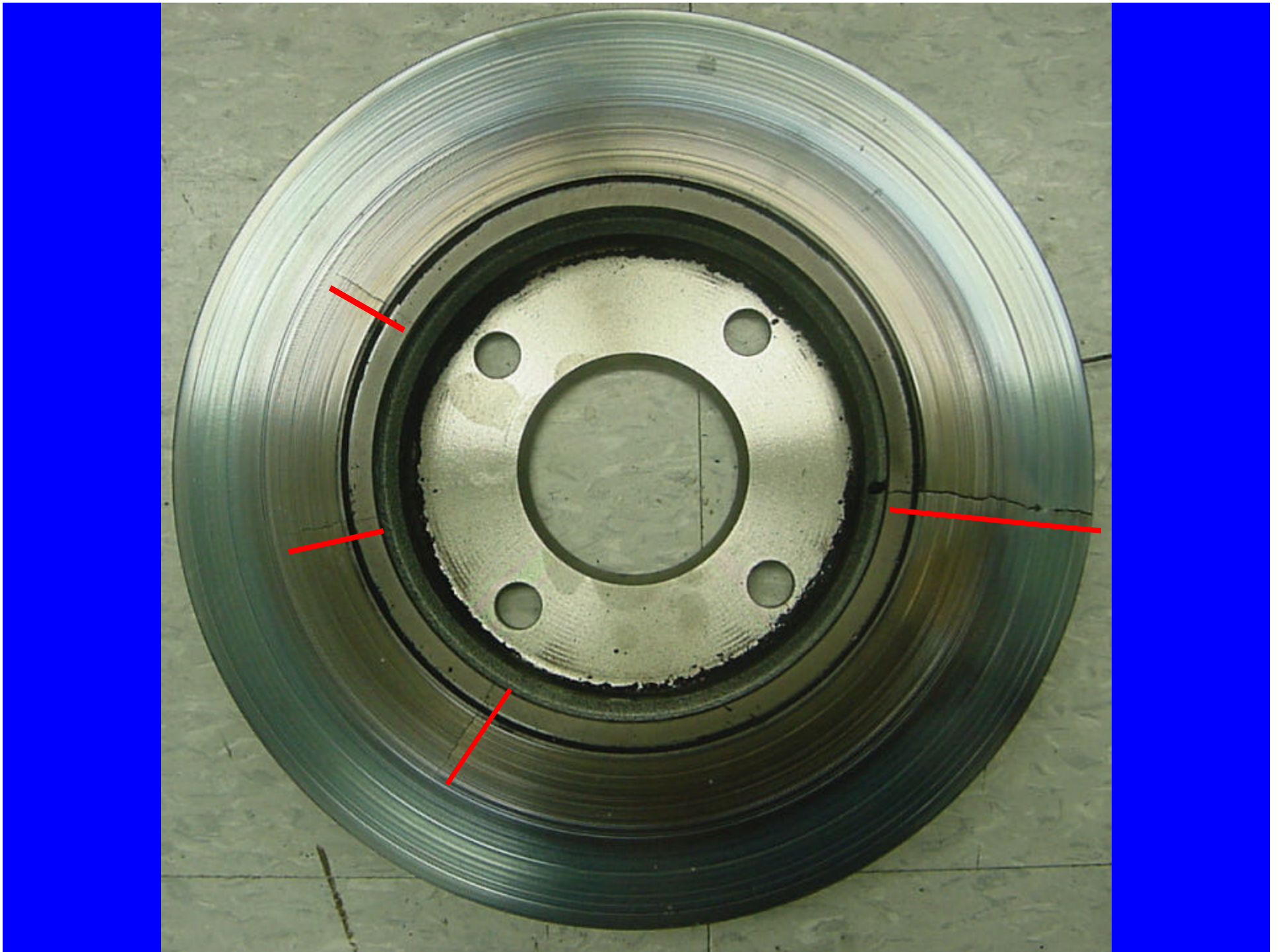
IR SENSOR System

Utilization of System

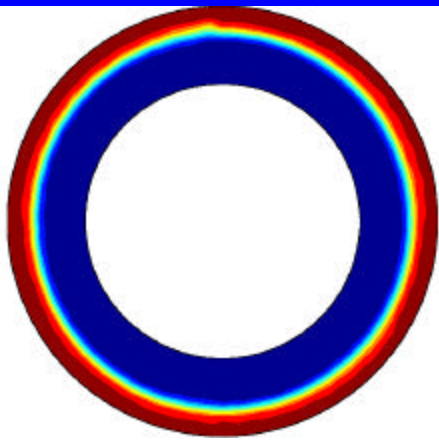
- Hot spot data used to validate new Thermoelastic Instability (TEI) model and show previous models were non-conservative.
- Rotor cracking root cause determined

Why do rotors crack in overload conditions?

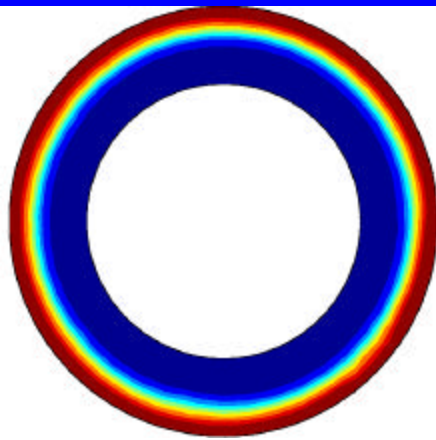
- 30% overload condition
 - Alternate 4 high G with 4 low G stops
 - Cracks in less than 50 stops
 - 200 High G stops – no cracks
 - 200 Low G stops – no cracks
- G = deceleration rate



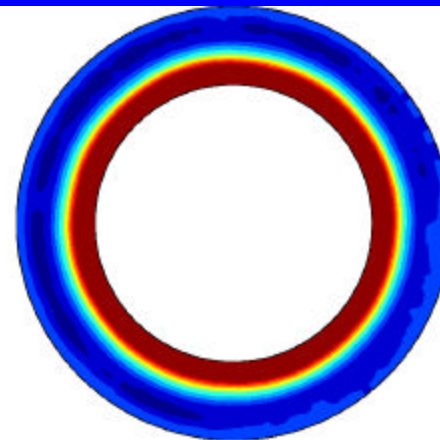
Rotor Temperatures



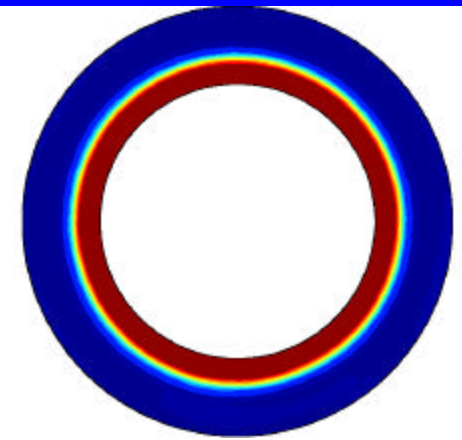
Inboard
High G



Outboard
High G

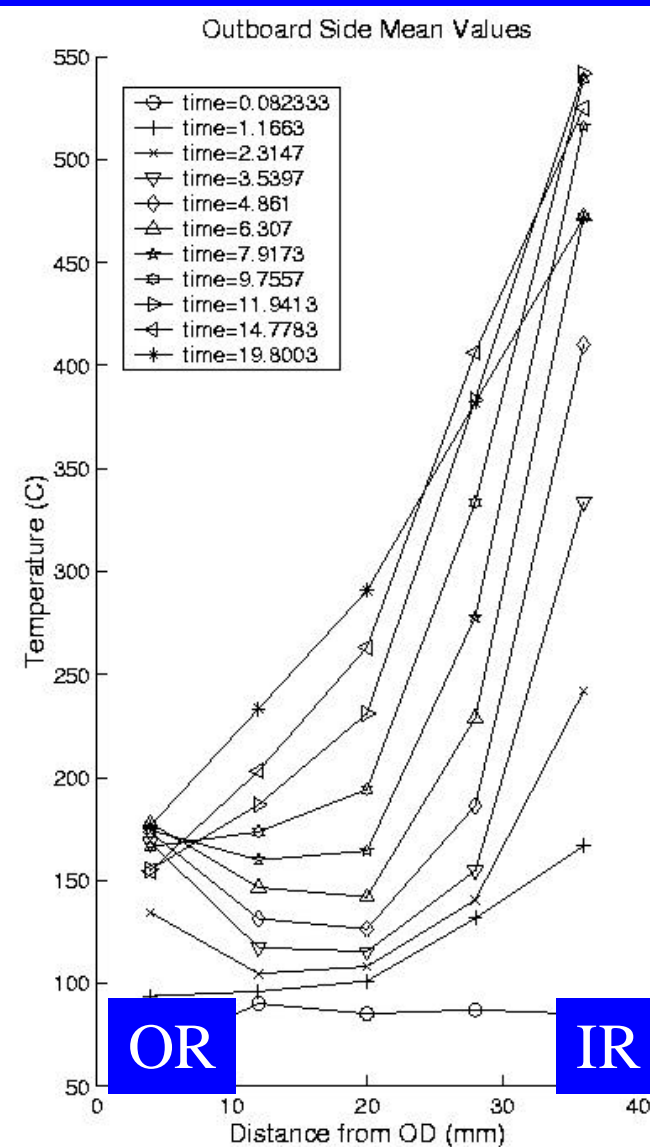
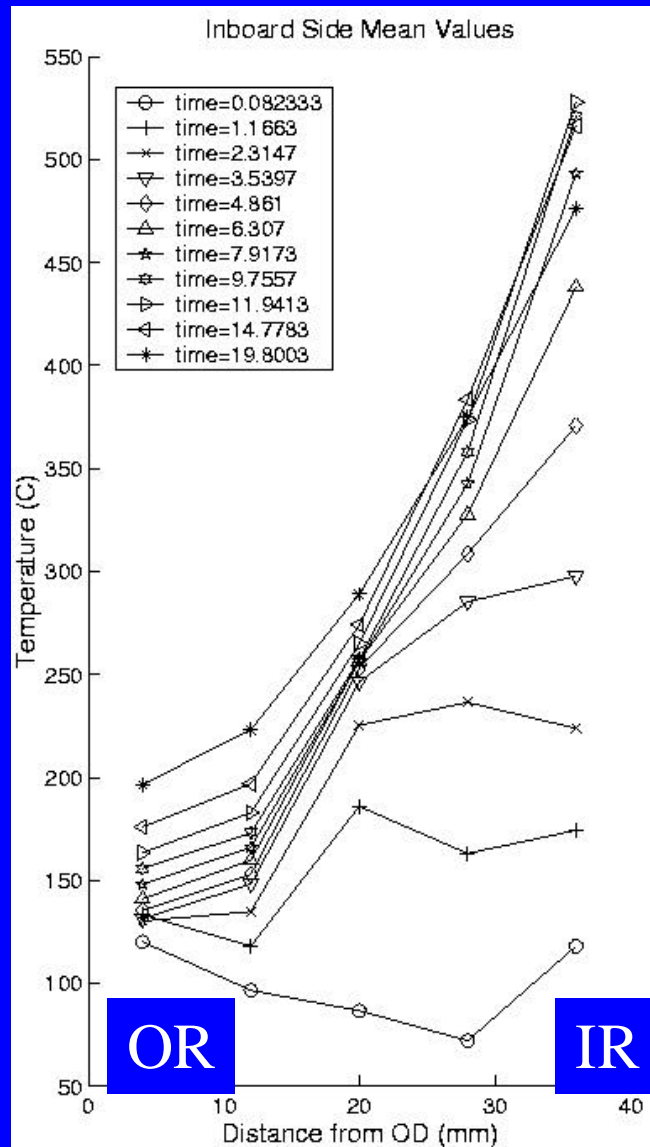


Inboard
Low G



Outboard
Low G

Time Dependant Temperature inputs – Low G

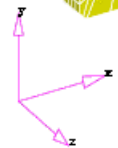
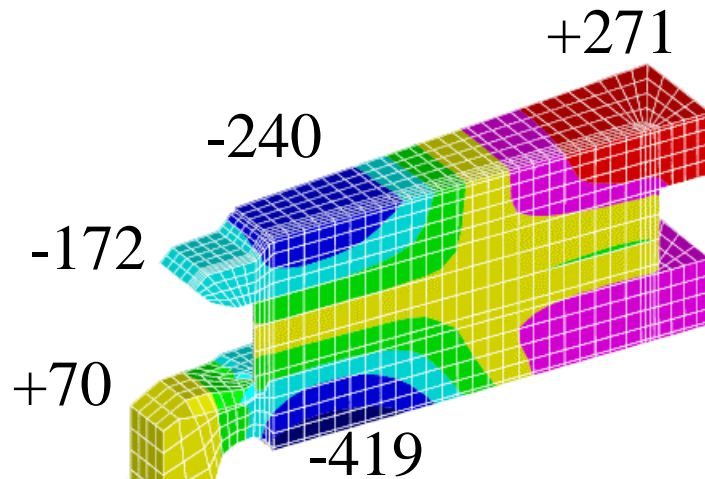
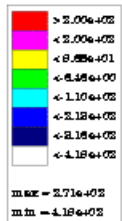


Stress Results – Phase 1

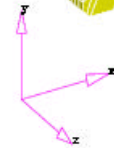
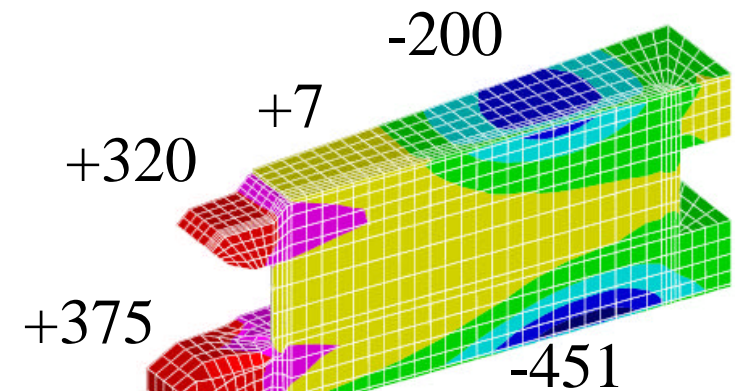
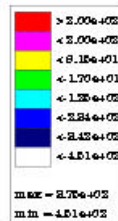
Low G Stop

High G Stop

step11inc117, t=1.15e+01
Show: ZZ (N)

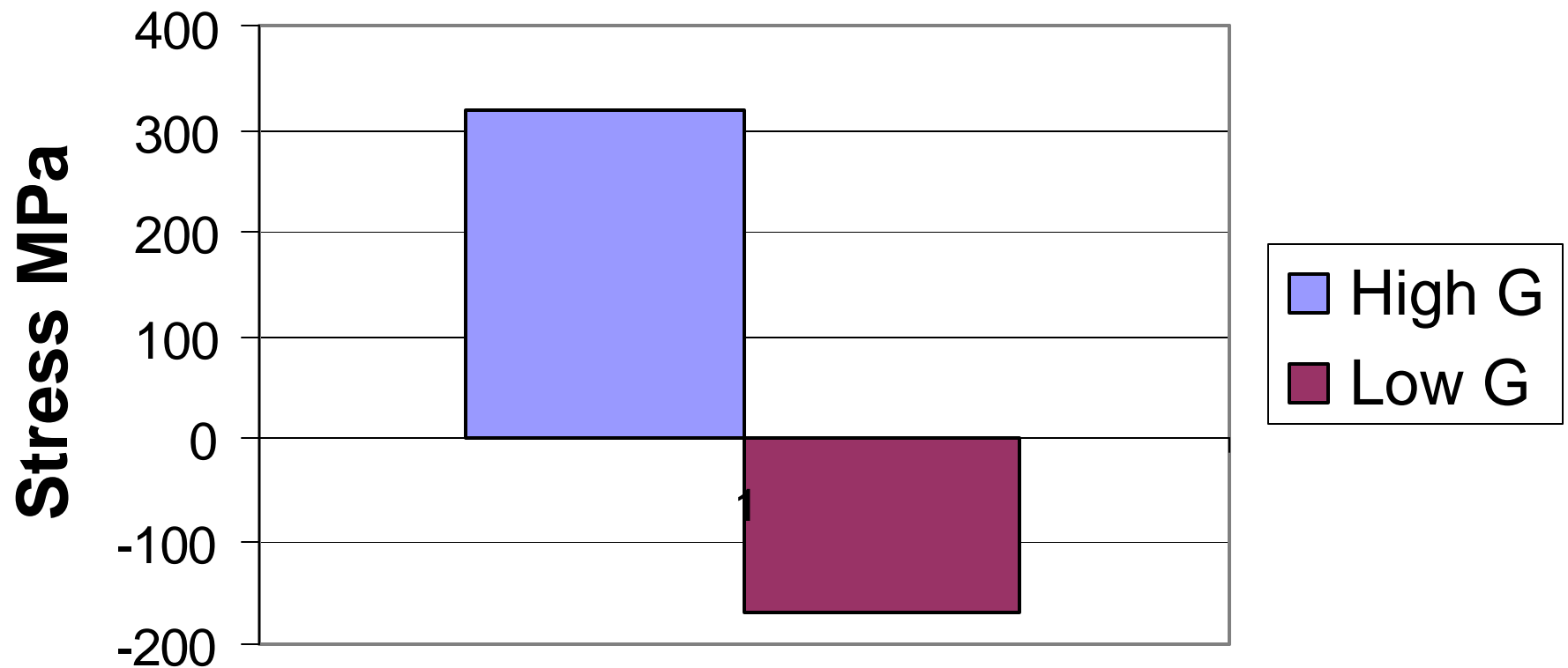


step11inc122, t=4.57e+00
Show: ZZ (N)



Stress Reversals

Stress in Lip for Phase 1



Utilization for Rotor Cracking

- IR sensor temperature data indicated bands of temperature on rotor
- IR sensor system provided data for FEA analyses to predict stresses
- Stress values successfully used to predict fatigue failures.
- Temperature banding caused by taper wear of the pads.

Conclusions

- Collaboration with ORNL in the development of the IR sensor system was very successful.
- The developed system has been used to validate models and identify root causes of problems, which is necessary to truly eliminate the problem.